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ABSTRACT

A longitudinal case study focused on the process of conceptual change in science of a young girl. The subject, the researcher's granddaughter, was 6 years and 6 months old and in first grade when the first of 19 hour-long sessions began. Sessions were spread over a two-year period. A concurrent case study was being conducted with the researcher's grandson. Tradebooks and discussion were used to provide scaffolded and developmentally appropriate science instruction. Data included field notes and interviews. Results indicated that (1) the developmentally appropriate instruction enabled both children to restructure their alternative conceptions of scientific principles; (2) both seemed to follow the same process of conceptual change (they at first held onto their ideas despite instruction, then underwent a period when they held alternative conceptions and ideas consistent with scientific understanding at the same time, and finally a time when they abandoned their alternative conceptions); (3) both children had to be encouraged to have confidence in themselves as learners at the same time that their confidence in their original ideas was being challenged for conceptual change to take place; (4) neither child demonstrated any evidence of a misconception about the cause of the seasons; and (5) the girl's response to anomalous data was to reject it while the boy appeared to accept it but did not retain it. Findings suggest that it is important to encourage young girls to show an interest in science and have confidence in their ability to learn and do science.(Contains 32 references and seven figures.) (RS)

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Conceptual Change in a Young Girl:

A Longitudinal Case Study

CONCEPTUAL CHANGE

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K. Maria

Paper Presented at the annual meeting of the National Reading Conference, Scottsdale, AZ, December, 1997.

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Conceptual Change in a Young Girl:
A Longitudinal Case Study

This study is a longitudinal case study focusing on the process of conceptual change in science: the process by which people restructure ideas that differ from accepted scientific understandings (alternative conceptions) and acquire scientific ideas. It was conducted with my grandaughter Jennifer (a pseudonym) from February 1992 to February 1994 at the same time that I was conducting a case study of my grandson Christopher (Maria, 1997). A vignette from this case study of Jennifer was previously presented at the National Reading Conference(Maria, 1994) and is part of a book in which researchers respond to this and other conceptual change vignettes from different theoretical perspectives (Maria, in press). However, the full results of the case study of Jennifer have never been presented or compared to the results of the case study of Christopher.

The Case Study

The case studies of Christopher and Jennifer focused on the process of conceptual change related to concepts about the shape of the earth, gravity and the causes of day and night and the seasons. These ideas were chosen for study because previous research in reading (Gordon, 1992a, 1992b; Maria, 1988; Maria & Hathaway, 1991; Maria & Johnson, 1990; Marshall, 1987) cognitive science (Vosniadou, 1987, 1992) and science education (Klein, 1982; Nussbaum, 1979; Nussbaum & Novak, 1976; Sneider & Pulos, 1983) indicated that many children and adults had alternative conceptions about these ideas even after receiving instruction in accepted scientific understandings.

Christopher and Jennifer were selected as informants for the case studies because they were young children. Most studies of conceptual change

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had been conducted with older children (i.e., Gordon, 1992a, 1992b; Maria, 1988; Maria & Hathaway, 1991). A few studies had established the existence of alternative conceptions about the earth in preschool children (Vosniadou, 1987, 1992), but these were cross sectional studies that did not document the process by which these alternative conceptions developed and changed. I hoped that longitudinal case studies would provide some insight into this process.

Novak and Musonda (1991) found that children who had been introduced to counterintuitive science concepts in the primary grades were less likely to develop alternative conceptions. I wanted to try introducing scientific ideas about the earth to even younger children in a developmentally appropriate manner because my previous research indicated that the alternative conceptions of older children were very resistant to change (e.g., Maria & Johnson, 1990). I reasoned that alternative conceptions in a young child might be less entrenched and thus more amenable to instruction.

Christopher and Jennifer were also both selected for study because they were my grandchildren. Their relationship with me permitted access to a richness of data unavailable to anyone outside the family and would make it possible to conduct follow-up studies when the children were older.

In addition, Christopher was selected for study because he had shown an early interest in science. Christopher liked to watch Mr. Wizard on television. He was interested in space exploration. He wanted to conduct experiments in which he ``made formulas''. Two weeks after selecting Christopher for study, I read an article in Newsweek magazine (Kantrowitz, Wingert, & Houston, 1992) documenting the gender gap in science achievement and suggesting that girls are not encouraged to enter the field of science. Recognizing that I was guilty of perpetuating a stereotype by asking my

grandson to participate in a science study but not my grandaughter, I immediately called Jennifer and asked her if she would like to be part of the study also.

Since Jennifer was selected for the case study after Christopher and because of her gender, questions investigated in conducting the case study with her were:

1. What were the similarities and differences between Christopher and Jennifer in their initial ideas about the earth, the process by which their ideas changed and the way in which they responded to instructional conditions including the trade books?
2. Did any of these differences appear to be related to gender? How did these differences affect Jennifer's process of conceptual change?

Method

Participants

Jennifer was 6 years and 6 months old and in first grade when the study began. Standardized testing at the end of first grade indicated that she was an above average student. Her mathematics ability had been recognized by her family, but before the study began she was not being encouraged in the development of this ability but was being guided toward more "feminine" pursuits (e.g. ballet lessons).

Since I am Jennifer's paternal grandmother, I was definitely a participant observer. Christopher, Jennifer's cousin, who is a year younger participated in four joint sessions with her.

Procedures

Jennifer and I met for 19 hour-long sessions in my home, usually seated side by side at the dining room table. Time between sessions ranged from one week at the outset to six months between the 18th and 19th sessions. (This

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increased separation between sessions was caused by three other grandchildren who also demanded to do science with Grandma.) However, throughout the study, I saw her at least once a week with the rest of the family, and took field notes concerning anything that happened relevant to the focus of the case study. In addition, I also interviewed her parents and other members of the family.

I followed the same procedure with Jennifer that I did with Christopher. In the early sessions, she was interviewed to determine what she already knew about earth concepts. In the later sessions, while continuing to probe understanding of more complex concepts like day and night and the seasons, I used tradebooks and discussion to provide scaffolded and developmentally appropriate science instruction (National Association for the Education of Young Children, 1989) about the earth within a social constructivist framework (Vygotsky, 1978). The theoretical framework, the instructional procedures and the methods of data collection and analysis were the same as those described in the case study of Christopher (Maria, 1997). The one difference was in the activities that the children chose to do in addition to the instruction about the earth. With Christopher I did chemical experiments. Jennifer and I studied about dolphins and whales, using videos and books and even going on a trip to a local aquarium.

Results

The case study of Christopher (Maria, 1997) described how Christopher constructed the alternative conception that gravity pulls to ``the bottom of space'' and how he abandoned this idea for the idea that gravity pulls to the center of the earth, an idea consistent with current scientific understanding. Jennifer had the same alternative conception. In our third session (4/12/92), I showed Jennifer a styrofoam ball with a hole through it,

asking her to pretend that the ball was the earth. When I asked her what would happen to a rock dropped through the hole, she told me it would go right through, ``because rocks don't stop''. Later in the session, when shown four pictures (See Figure 1) and asked which one showed what would happen to a ball dropped through an imaginary hole in the earth, like Christopher she chose picture 4, the picture that showed the ball dropping through the hole.

Insert Figure 1 here

Maria (1997) described the conceptual conflict that Christopher experienced when I asked him to do the same task. Although previously in the session, Jennifer had said that a person who lived in Australia would not fall off the earth because of ``something sticky on there'', she did not appear to experience conflict when she indicated that the ball would fall through the earth. However, she did immediately ask me if she was right.

Like Christopher, Jennifer held onto her alternative conception for a long period of time, at times alternating between the alternative conception and the idea consistent with scientific understanding and at times appearing to hold both ideas at the same time. In the fifth session (5/9/92), a session at which Christopher was also present, Jennifer recalled that in the previous session,she said people did not fall off the earth.

K: And why wouldn't you fall off the earth?

J: Cause the earth is round.

K: Yes. But what would you say is keeping you on the earth?

J: Gravity.

K: Oh! You said gravity. What is gravity?

J: Gravity is what makes you stay to the ground.

K: So what is it?

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J: Gravity is something you don't see, but it keeps you on the ground. If, you were here (pointing to Australia), you wouldn't fall off the earth.

(Session 5, 5/9/92)

Later in the session, we read the book, Gravity is a Mystery (Branley, 1986)which described what would happen to a person if he fell through an imaginary hole in the earth, i.e. he would be pulled toward the center. In Maria (in press), I describe how Jennifer rejected this explanation and labeled the book ``a fairy tale''. When I tried to defend the ideas in the book as true, she argued that it could not be true because no one could go to the center of the earth, ``they would burn up'' and pointed out to me the fallacy in my logic when I tried to defend the book's explanation.

The picture that Jennifer drew in her journal at the end of the session is rather ambiguous. There is a line going through the earth but an X at the center. Jennifer directed me to write on her picture `` You can fall in the middle of the earth if you dig a hole. You will stop in the center of the earth. You could get heated up when you get to the middle - burnt''. Jennifer seemed to be engaging in a ``procedural display'' (Bloome, Puro, & Theodorou, 1989), i.e., saying what she thought I wanted her to say without really believing it. In our next session and several sessions after that she continued to hold onto the idea that something dropped through a hole in the earth would fall to ``the bottom of space''.

Insert Figure 2 here

Christopher seemed to accept information I presented even though he later reverted to his alternative conception. However, for a long time, Jennifer rejected information that conflicted with her alternative conception. In our sixth session (6/15/92) given the pictures again she again

picked the one showing the ball falling through the earth. Later in the session, I showed her Gravity is a Mystery.

K: If you dig a hole in the earth, do you remember where it said you would end up?

J: In the middle.

Using an inflatable globe with figures of children stuck to places in the Northern and Southern hemispheres, I asked her where rocks would go if the children dropped them through a hole in the earth. She indicated that they would fall into space. When she was asked to compare her ideas to the ideas in the book, she came up with a new alternative conception about gravity to defend her old one.

K: But this book says different, right?

J: Yes.

K: ...This book said that it would end up in the center of the earth, but you think that's not right.

J: Right.

K: Why do you think the people wrote that it would end up in the center of the earth?

J: Because they might think it was the gravity and there was no gravity in there.

(Session 6, 6/15/92)

Chinn (in press) suggested asking students who are learning a scientific theory two sets of questions. The first set of questions like the questions I asked Jennifer about what the book said would test children's knowledge about the new ideas. The second set of questions would test the children's belief in the new ideas. Although I was not aware of Chinn's suggestion at

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the time by asking these two types of questions I was able to determine that although Jennifer knew what the book said she did not believe it.

Maria (in press) provides the evidence that in our sixteenth session (5/20/93) Jennifer abandoned her alternative conception for an idea consistent with scientific understanding after we made a personal connection for her. I related my trip to South America where I did not fall off the earth to the ideas presented in Gravity is a Mystery. The evidence that I did not fall off the earth was also what seemed crucial in changing Christopher's alternative conception. Other aspects of instruction:models of the earth, tradebooks and discussion about the tradebooks were helpful to Jennifer as they were to Christopher (Maria, 1997).

Although Jennifer and Christopher were similar in their alternative conception about gravity and the process by which they changed this alternative conception, there were many differences between them. Perhaps because Jennifer had not shown any interest in the physical sciences before the study began, she intially had less knowledge about the concepts that were the focus of the study than Christopher did. At the beginning of our sessions, Christopher was using terms like gravity and force, to explain why his tower of blocks fell down. As described above, Jennifer talked about ``sticky stuff like glue'' that held us to the earth. However, as I worked with Jennifer I became aware that although she did not share Christopher's interest in the physical sciences of chemistry and astronomy, she was interested in biology. She carefully observed the behavior of her cat and was interested in how plants grew. In our early sessions, she used terms that she had learned in school like mammals and gills when she was talking about animals. This interest was consistent with the finding that girls tend to focus on life sciences rather than physical sciences (Jones & Kirk, 1990;

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Kahle, Parker, Rennie, & Riley, 1993). As a result of our sessions about the earth, however, Jennifer did become more interested in earth science and astronomy. She and her father made a model of the solar system for the first grade science fair, and she bought books about the earth at the school book fair. However, she continues to be more interested in animals and has discussed becoming a veterinarian or a marine biologist when she grows up.

Jennifer had more alternative conceptions about the earth than Christopher. At the outset of the study, Christopher knew that the earth was a round sphere surrounded by space, that people lived on the outside of the earth and that people do not just live on the top of the earth. Jennifer's answers to questions about the earth in our first and second sessions were very hesitant and suggested that she might view the earth as a flat disc. At the beginning of the second session we read a portion of the tradebook, Our Planet Earth (Wood, 1992). Jennifer had bought this book at her school book fair because she thought it would be good for ``studying about the earth''. A picture on the second page of the book showed the earth as a round sphere surrounded by space. In the picture the moon was below the earth. The placement of the moon disturbed Jennifer. She told me that the moon was in the wrong place because the moon should shine down, thought for a moment and then said ``Maybe because the earth spins'', but then said ``I know. Maybe the man who drew it held it upside down.'' This rejection of the anomalous data presented by the book together with her answers to the questions suggest that she came to the study with a Notion 1 view of the earth as a flat disc with the sky above (Nussbaum, 1979).

Unlike Christopher, Jennifer had the alternative conception that people lived inside the earth. Their different views at the beginning of our

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sessions can be seen by comparing the pictures that they both drew when asked to draw the earth with themselves on it.

Insert Figures 3 and 4 here.

Maria (in press) describes how this alternative conception interacted with Jennifer's alternative conception about gravity and how she eventually understood that we live outside the earth but cannot see space because of the atmosphere. The picture she drew in her journal at the end of our fifteenth session (5/1/93) provides evidence of her new view of the earth.

Insert Figure 5 here.

Unlike Christopher, throughout the study Jennifer indicated that the movement of the earth not the sun caused day and night. Following is a transcript of her responses the first time that she was asked about day and night.

K: Does the earth move?

J: A little bit. It turns very slow.

K: Our earth that we live on turns slowly?

J: Because it goes slowly around the stars.

K: Can you tell me what causes day and night?

J: Because while the earth turns, it turns slowly so it's night time and then it turns to the other side. It turns daytime.

K: Does the sun move?

J: No, only the earth.

(Session 4, 4/12/92)

Although her statements here sound like she understands that the rotation of the earth causes day and night, on many subsequent occasions Jennifer suggested that day and night were caused by the revolution of the earth around the sun. Christopher also had this idea at first but seemed to

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move away from it. Despite repeated instruction in which we read tradebooks, The Sun is Always Shining Somewhere (Fowler, 1991), What Makes Day and Night (Branley, 1986b) and Day and Night (Nelson, 1990),that explained about rotation, danced the two movements of the earth and used balls and a flashlight to demonstrate the effect of the earth's spinning, Jennifer was still confused about the movements of the earth at the end of the study. I describe this idea as a confusion rather than an alternative conception because although her ideas about day and night were incorrect they were not based on intuitive ideas, a criteria Maria (1997) suggested for identifying an alternative conception.

Like Christopher, at the outset of the study Jennifer understood that there were four seasons. She could name the seasons in correct sequence and describe the weather and many things that happened in nature during the different seasons. From February 1993 until May 1993, every time we met Jessica and I noted the time of sunrise and sunset. In our sixteenth (5/20/93) session, I asked Jessica for the first time about the cause of the seasons. She indicated that she did not know. We went over the records that we had kept. Through my questioning Jessica discovered the pattern of longer days.

K: Okay. I said to you before, ``Why is it hotter in summer and colder in winter. You can tell me a little bit now - one reason why it's hotter in summer.

J: Because the sun has five more hours of sunlight.

(Session 16, 5/20/93)

We then played with the orbiter planetarium (Delta, 1993) a model that shows the tilt of the earth during the four seasons. (She and Christopher had both played with it at a family gathering several weeks before and

discovered that during the summer the northern hemisphere was tilted toward the sun and during the winter it was tilted away from the sun.) Jennifer noticed this again and wrote in her journal.

Insert Figure 6 here.

I pointed out that she needed to say northern hemisphere rather than the earth because the seasons are opposite in the different hemispheres. Although she seemed to understand the cause of the seasons, in a later session (9/25/93) she and Christopher both showed some confusion about the relationship of the earth's tilt to day and night and the seasons. Like Christopher, however, Jennifer never gave any indication that she had the common misconception that summer is warmer because the earth is closer to the sun.

One difference between Christopher and Jennifer that I attributed to her gender was her interest in the life sciences rather than the physical sciences. Another difference I noticed seemed to be to be related to her gender although it could just be a difference in the personalities of the two children. At the outset of the study, whenever Jennifer was asked a question, she asked if her answer was right as she did the first time she was asked what would happen to a ball dropped through the earth. Christopher never asked if his answer was right. This bothered me because it seemed to me to indicate a lack of confidence typical of girls and women in educational and social situations (e.g. Gallas, 1995; Tannen, 199). Pintrich et al. (1993) highlight the role of confidence in the process of conceptual change referring to it as a two-edged sword. In order to be open to change, learners cannot have too much confidence in their ideas, but in order to change their ideas they must have confidence in themselves as learners. Thus whenever Jennifer asked me if she was right, I told her that

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was not important. The important thing was to think carefully and have good reasons for saying what you believed. I urged Jennifer not to ask whether she was right but to think carefully and then state her ideas with confidence. When Jennifer began rejecting ideas that conflicted with her alternative conceptions, I sometimes wondered whether my advice was interfering with her learning. Yet I realized that in acting this way, she was no different from many people over the years. So I validated her ideas by pointing out how they were similar to what many people had believed in the past. But I also challenged her ideas pointing out aspects of them that were not in agreement with scientists' views and/or evidence from nature, helping her to see that her ideas and her process of conceptual change were just like the changing story of science.

Unlike Christopher, Jennifer had to develop confidence in her own ideas. Like Christopher, she also developed confidence in herself as a learner so that she was able to change those ideas. In our eighteenth session (9/25/93) Christopher, Jennifer and I did an experiment to determine which color shirt would be hotter when placed in the sun. Jennifer confidently predicted that it would be the white one, but recognized that her hypothesis was incorrect and happily recorded the results of the experiment in her journal.

See Figure 7

Last June I interviewed Jennifer's sixth grade science teacher. She described Jennifer as ``fearless. She asks when she doesn't understand something. She's not self conscious like most kids. Sometimes I lose her. I used to think she was daydreaming, but I discovered that she is contemplating something that we were talking about. Isn't that what you want for them at this age - to put it in their own words and really

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understand it?'' In reply to my questions, she described Jennifer as confident in herself as a learner but not confident in her own ideas.

Discussion

Since this case study is a replication of the case study done with Christopher (Maria, 1997), it provides further support for the findings of that study. First, the developmentally appropriate instruction centering on tradebooks and discussion about them enabled Jennifer as well as Christopher to restructure their alternative conceptions. Second, both of them seemed to follow the same process of conceptual change. At first there was a period in which they held onto their original ideas despite instruction, then a period when they seemed to hold alternative conceptions and ideas consistent with scientific understanding at the same time and finally a time when they abandoned their alternative conceptions for ideas consistent with scientific understanding. Third, this study provides further support for Pintrich et al's (1993) ``hot model of conceptual change''. Both children had to be encouraged to have confidence in themselves as learners at the same time that their confidence in their original ideas was being challenged in order for conceptual change to take place. Fourth, the fact that neither child demonstrated any evidence of a misconception about the cause of the seasons suggests that this common misconception may develop during the school years possibly as the result of instruction. I plan to investigate this hypothesis in follow up studies of Christopher and Jennifer.

This case study also allows us to see differences in the conceptual change process for the two children. Chinn and Brewer (1993) described the different responses that learners can give to anomalous data. The two children's reponses were different. Jennifer's response to anomolous data was to reject it while Christopher appeared to accept it but did not retain

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it. However, both kinds of responses resulted in the children's failure to abandon their alternative conceptions.

This case study of a young girl suggests that it is particularly important to encourage young girls to show an interest in science and have confidence in their ability to learn and do science. At the outset, Jennifer knew less about earth science and had more alternative conceptions than Christopher did even though she was a year older. She also had less confidence in herself. However, the supportive instruction provided to her enabled her to catch up with Christopher, to consider science as a possible occupation and to develop the self confidence that she continues to demonstrate as she approaches adolescence.

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Figure 1
Pictures presented to Jennifer in the interview about gravity
(Session 3, 4/12/92)

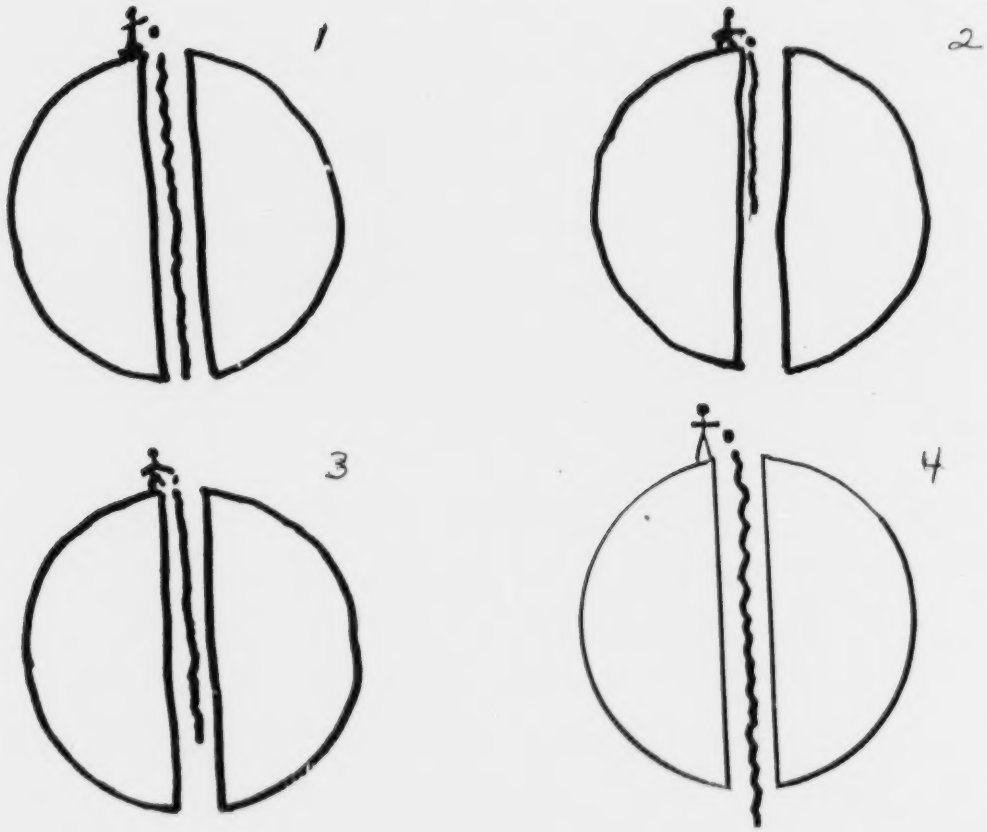

Figure 2
Picture from Jennifer's Journal
(Session 5, 5/9/92)

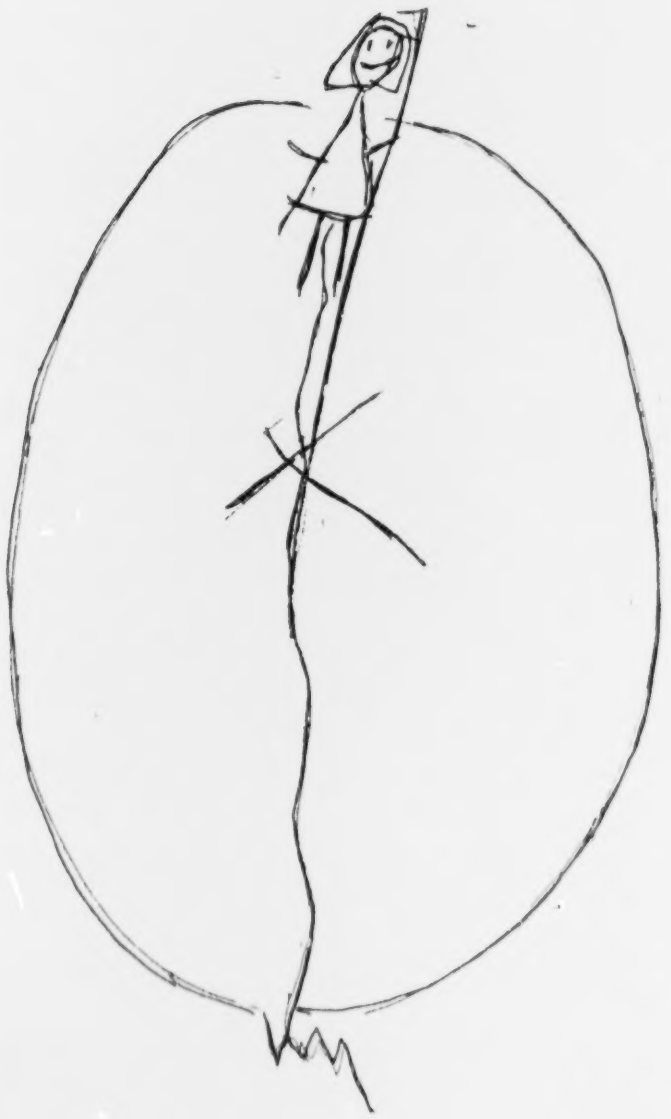

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Figure 3
Jennifer's Initial View of the Earth
(Session 1, 2/24/92)

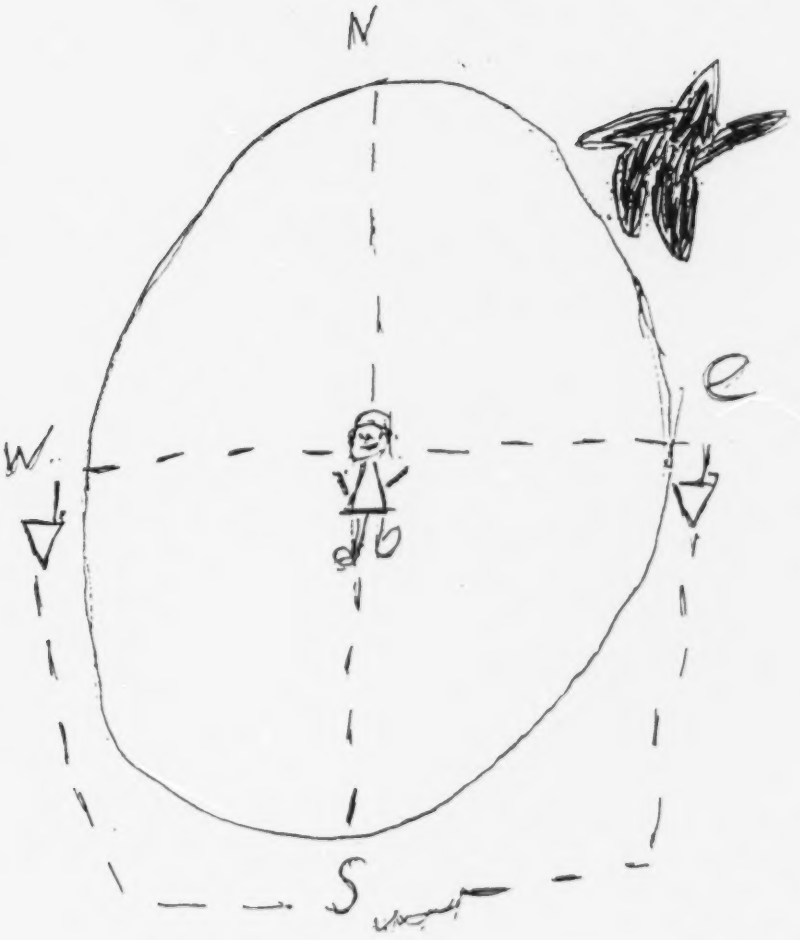

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Figure 4
Christopher's Initial View of the Earth
(Session 4, 3/22/92)

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Figure 5
Jennifer's Picture of Herself Dropping a Rock
through a hole in the earth
(Session 15, 5/1/93)

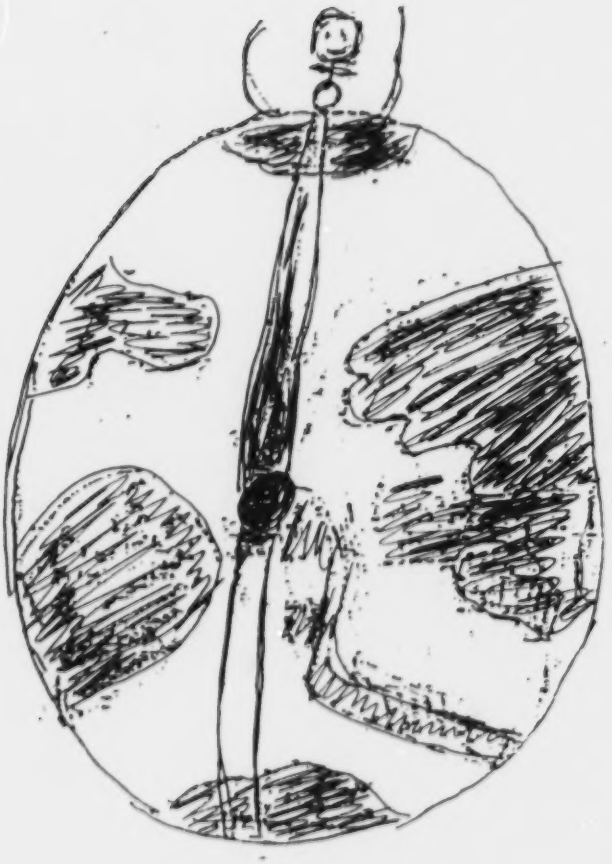

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Figure 6
Jennifer's Journal Entry about the Seasons
(Session 16, 5/20/93)

How The Earth tills. In the summer the northern hemisphere earth tills to sun. In winter the northern hemisphere sun is tiled away from the sun.

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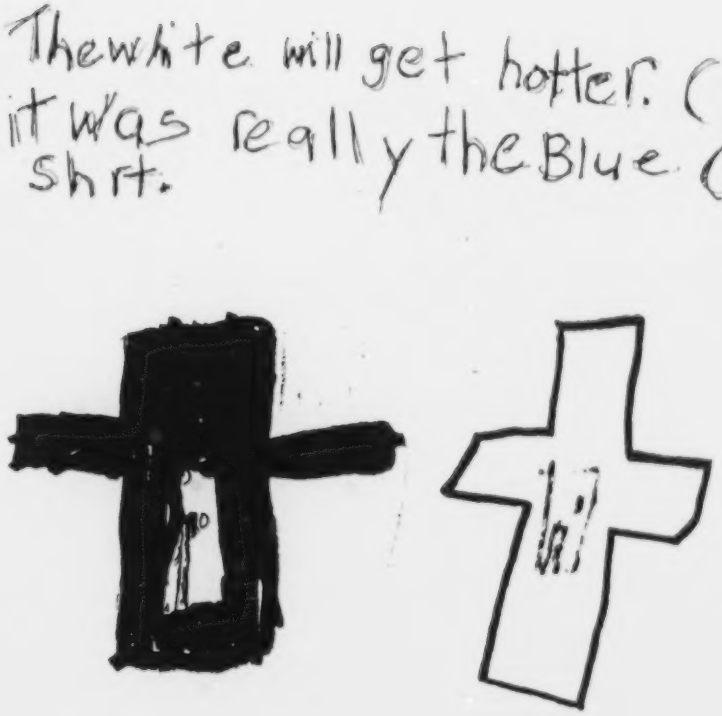
Figure 7
Jennifer's Record of Results of the Shirt Experiment
(Session 18, 9/25/93)



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